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## **Risk / Benefit-Cost Analysis**

# **PROHIBITING HAZARDOUS MATERIAL IN EXTERNAL PIPING OF MC 306 / DOT 406 CARGO TANK MOTOR VEHICLES**

## **Preliminary Assessment**



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Research and Special Programs Administration  
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DHM-20**

2.7. million

## EXECUTIVE SUMMARY

As a result of recent incidents, on May 18, 1998, the National Transportation Safety Board (NTSB) recommended that the Department of Transportation prohibit the carrying of all hazardous materials in unprotected external piping of cargo tank motor vehicles, such as loading lines, that may be vulnerable to failure in an accident. Secretary Slater responded to the NTSB indicating DOT shares the concerns of the Board with respect to potential loss of life and injury and the intent of the recommendation. Secretary Slater noted that RSPA would prepare a preliminary risk / benefit-cost analysis to help determine potential courses of action and justification for possible rulemaking.

This analysis is a **first-cut** look at risks inherent in the current system, the level of technology development and possible ways to eliminate or reduce risk, and benefits and costs of various approaches. The analysis centers on gasoline because of its high contribution to overall risk and the belief that action could most likely be justified for this commodity

Our best estimate of the number of fatalities attributable to wet lines in gasoline transportation is 0.70 per year. The number of major injuries per year attributable to wet lines in gasoline transportation is estimated at 0.52 per year. Expected value of property damage attributable to wet lines in gasoline transportation is estimated at \$800,000. The total value of wet line risk avoidance, including values for fatalities, injuries, and property damage is estimated at \$3 million per year.

At least two systems show promise in eliminating risk from wet lines. One uses an **onboard** pumping or purging system to move product from the wet lines to a main tank compartment. The other adds a second set of lines for loading that retains a minimum amount of product which, while not eliminating risk, reduces it. There are weight penalty costs to both systems, but neither add operating time to the system which is critical from a benefit-cost standpoint. Other solutions to the problem may exist.

Analysis of the present value of costs and benefits to eliminate wet lines results in cost to benefit ratios of about three to one in the best instance. However, there are enough uncertainties in enough areas, such as data and cost estimates, such that the figures fall within the realm where corrective action needs to be considered. Ultimately, transportation of hazardous materials such as gasoline in wet lines is not a good practice with **finite**, albeit less than **great**, consequences that can be avoided without tremendous costs or disruptions to the industry.

## **Preliminary Assessment Risk / Benefit-Cost**

### **Prohibiting Hazardous Material in External Piping of MC 306 / DOT 406 Cargo Tank Motor Vehicles**

#### **Background:**

On May 18, 1998, the National Transportation Safety Board (NTSB) recommended that the Department of Transportation prohibit the carrying of all hazardous materials in unprotected external piping of cargo tank motor vehicles, such as loading lines, that may be vulnerable to failure in an accident. On August 31, 1998, the Research and Special Programs Administration (RSPA) began a preliminary risk/benefit-cost assessment to help determine potential courses of action and justify possible rulemaking, if warranted.

The NTSB recommendation was issued following an investigation of an October 9, 1997 accident involving a MC 306 cargo tank semi-trailer carrying approximately 8,800 gallons of gasoline in Yonkers, New York. A car struck the right side of the cargo tank in the area of the loading /unloading lines causing the release of approximately 28 gallons of gasoline contained therein. An ensuing fire spread to the product within the tank itself, killed the driver of the car, who would have otherwise survived, and destroyed both vehicles and an overpass of a freeway. Property damage was estimated at \$7 million. The incident is described in NTSB report NTSB/HAR-98/01/SUM (Reference 1).

#### **Purpose:**

This analysis is a preliminary look at the risks inherent in the current system of operating cargo tank motor vehicles with the external piping filled with flammable and combustible liquids. Benefits and costs of alternatives are considered. The purpose of this analysis is to develop enough information to help make risk and cost informed judgments whether to proceed with rulemaking or other approaches to eliminate risks from wet lines in flammable and combustible hazardous material transportation. Further data and analysis may be necessary for

longer term decision-making processes.

Because of the more volatile nature and hazard of the product, the amount transported, and its high contribution to overall risk, this analysis centers on gasoline in the belief that action, if any, is most likely to be justified for wet lines involved in the movement of this commodity. A full prohibition from carrying hazardous materials in external piping of cargo tanks that may be vulnerable to failure in an accident would extend to fuel oil, crude oil, jet fuel, aviation gasoline, alcohol, solvents, and other flammable and combustible liquid transportation. Further analysis may be in order to determine the most reasonable boundaries for such a prohibition.

### **Cargo Tank and Wet Lines Description:**

MC 306 and DOT 406 cargo tank motor vehicles are most frequently used in gasoline and fuel oil transportation. Most cargo tank motor vehicles in service today were built to MC 306 specifications. Cargo tank motor vehicles built after September 1, 1995 are required to meet the DOT 406 specifications. These cargo tank motor vehicles are the predominant **over-the-road** transportation conveyances for petroleum products.

MC 306 and DOT 406 cargo tank motor vehicles are non-pressurized (4 psi maximum) with a cargo capacity typically between 7,500 and 9,200 gallons. They can be constructed from mild steel, stainless steel, or aluminum. Most are constructed from the latter material because of weight considerations.

Cargo tank integrity is protected from collisions involving piping by shear sections on the external piping that fail first in event of an accident and by internal valves to stop the flow of product. Tanks are normally filled by pumping product through the external piping which carries 30-50 gallons of gasoline from loading to the **first** delivery stop (hence the term “wet lines”). As presently configured, there is no way in normal operation to evacuate the external lines by a sequence of **valve** closures since the lines are under pressure. The opportunity exists at the **first** delivery when gravity is used to drain product. External lines from compartments that have been unloaded are empty during subsequent transportation.

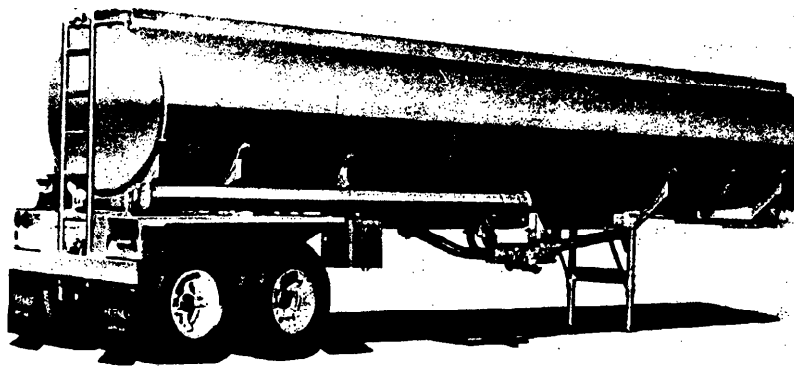
Wet lines are vulnerable in a side impact by an automobile. Clearance between the roadway

and a cargo tank is normally between 2' and 4'. An average automobile will typically under-ride the cargo tank in a collision from the side and can damage the external piping. Larger vehicles such as vans, sports utility vehicles, or other trucks pose more of a danger to the cargo tank itself in a side collision.

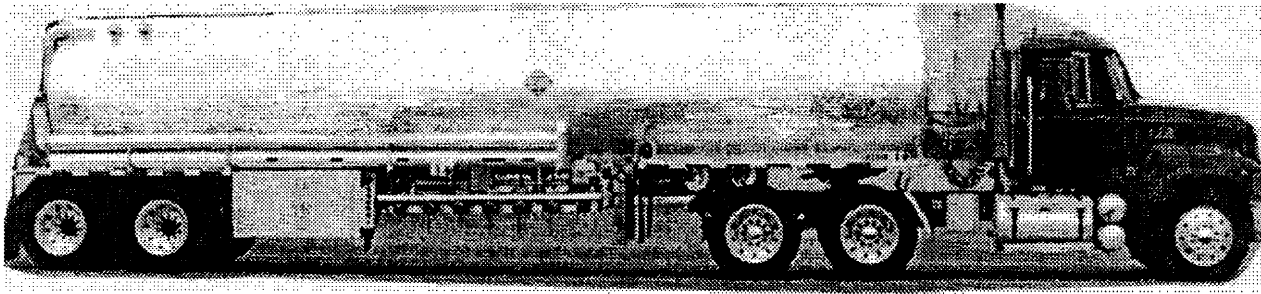
RSPA has long been concerned about the potential for loss of life and injury due to transportation of hazardous materials in wet lines of cargo tanks. Approximately 10 years ago, RSPA proposed eliminating unprotected wet lines in the transportation of all such material (HM-183). Final rules effective in 1990 prohibited carrying poisonous, corrosive, or oxidizer liquids in external piping unless the piping is protected by substantial guards.

RSPA reluctantly agreed at that time to except gasoline and other flammable liquids from the final rule because of strong industry objections based on the cost impact of changes, the relatively low level of risk that could be demonstrated, and the fact that a system to empty wet lines after loading was not available. RSPA challenged industry to find ways to eliminate the risks in a cost-effective manner.

Figures 1 and 2 are typical of MC 306 / DOT 406 cargo tank motor vehicles. Figure 2 shows a tank trailer with the tractor attached. Note the saddle tank on the vehicle, with a capacity of about 300 gallons, that poses risks in a collision not unlike those of wet lines except that diesel fuel is less volatile than gasoline.



**Semi-Trailer**  
**Figure 1**



**Semi-Trailer with Tractor Attached**  
**Figure 2**

### **Distribution System:**

Most crude oil movement to **refineries** and most **finished** gasoline movement to bulk storage terminals is by marine vessel or pipeline because of economics. One exception is that crude oil may be gathered from individual wells or fields in this country by cargo tank motor vehicle and delivered to pipeline storage locations or **refineries**. Movement of gasoline from bulk storage terminal to retail outlets or gas stations is almost always by cargo tank motor vehicle. There are approximately 15,000 bulk storage facilities with associated loading racks and about 170,000 gasoline retail outlets in the United States (Reference 2). The former could be affected by certain types of changes that would eliminate gasoline wet lines.

Daily consumption of motor gasoline in the United States is approximately 7,900,000 barrels, or 332,000,000 gallons. Shipment of this entire amount in nominal 8,000 gallon cargo tanks yields 42,000 shipments per day. Assuming a factor of 1.2 to account for shipment from bulk storage to intermediate or jobber storage and subsequent reshipment results in bulk shipments on the order of 50,000 per day or 18,000,000 per year.

A part of the **final** transportation **segment** for gasoline delivery to retail outlets occurs in smaller truck-mounted tanks. In its estimate of hazardous materials shipments (Reference 3 with information extracted and expanded in Appendix 1 ), **RSPA** estimates approximately 12% of the average annual consumption of gasoline reaches retail outlets in cargo tank motor vehicles of nominal 2000 gallon size, with shipment in these size vehicles accounting for about 30% of the number of **all** motor gasoline shipments.

### **MC 306 and DOT 406 Truck Count:**

As discussed earlier, the MC 306 and DOT 406 series are the predominant cargo tank motor vehicles for gasoline service. Although a precise count of this type of truck is not available, it is possible to make a rough estimate. The 1992 Truck Inventory and Use Survey indicates 232,000 tank trucks are in liquid or gas service. The total includes vehicles that haul non-hazardous materials such as milk and other food products. Data compiled by the Truck Trailer Manufacturer Association (**TTMA**) indicate tank trailer shipments for the 13 year period 1984-1996 for flammable and combustible liquids are 22,626 units out of a total of 58,714 tank trailers. After allowing for a comparatively well known number of vehicles in liquified compressed gas service, an extrapolation of this ratio to the overall fleet would indicate approximately 80,000 cargo tank motor vehicles, both single-unit trucks and tractor trailer combinations, are in flammable or combustible liquid service. Scaling **TTMA** data for tank trailer production to a 30 year period would indicate over 52,000 tank trailers alone are in flammable or combustible liquid service.

The **NTSB** in their report on the Yonkers, New York, incident cites a 1984 analysis by Dynamic Sciences, performed for the DOT in support of **HM-183**, that estimates the number of MC 306 vehicles at 57,900. The **NTSB** believes, however, that the current number of MC 306 and **DOT-406** cargo tank motor vehicles is larger than the 1984 estimate suggests. **RSPA** notes that gasoline consumption in the United States has increased by almost 20% since this earlier time frame, leading credence to this argument.

Scaled simply to accommodate gasoline shipments with each vehicle making an average of 3 shipments per day would require an active fleet of about 22,000 vehicles. (Comments in

earlier rulemaking indicate the average trips per cargo tank motor vehicle per day may approach 4). The actual number of cargo tank motor vehicles would necessarily have to be larger because not all vehicles are in operation at one time; matching transportation needs to vehicles to obtain full utilization is a practical impossibility in such a large system; a seven day a week schedule is not maintained by all operators; and other commodities, such as fuel oil, are carried by this type of vehicle.

For purposes of this analysis, it is assumed that 50,000 cargo tank motor vehicles would be affected by prohibiting the transportation of gasoline in external piping of cargo tanks. Because there is some seasonal variation in the use of the vehicles and they can carry gasoline, fuel oil, and other products in different cargo tank compartments, a relatively high percentage of the fleet would be affected. If a greater degree of vehicles can be dedicated to service for specific products and if only tank trailers are considered for changes due to potentially greater vulnerability, the number of vehicles affected specifically for gasoline transportation may be smaller. Costs calculated later in this analysis can be scaled to adjust for vehicle count.

### **Estimate of Fatalities and Major Injuries:**

The expected number of fatalities and injuries during flammable and combustible liquid transportation due to the hazardous nature of the material being transported is a function of the mileage driven, the accident rate, the probability of a spill given an accident, the probability of fire or explosion given a spill, and the probability of a fatality or injury given a fire or explosion.

Actual incident history should provide a relatively good indication of risk with respect to flammable and combustible material transportation. Significant quantities of material are transported. Because of the nature of the product, predominant risk is from accidents of limited consequences with one to a few fatalities. This contrasts with other hazardous materials such as toxic-by-inhalation materials like chlorine or liquefied petroleum gases where low probability, high consequence events have a more dramatic effect on the risk spectrum. Appendix 2 profiles this risk for gasoline transportation.

The Hazardous Materials Information System, HMIS, captures historical data on incidents

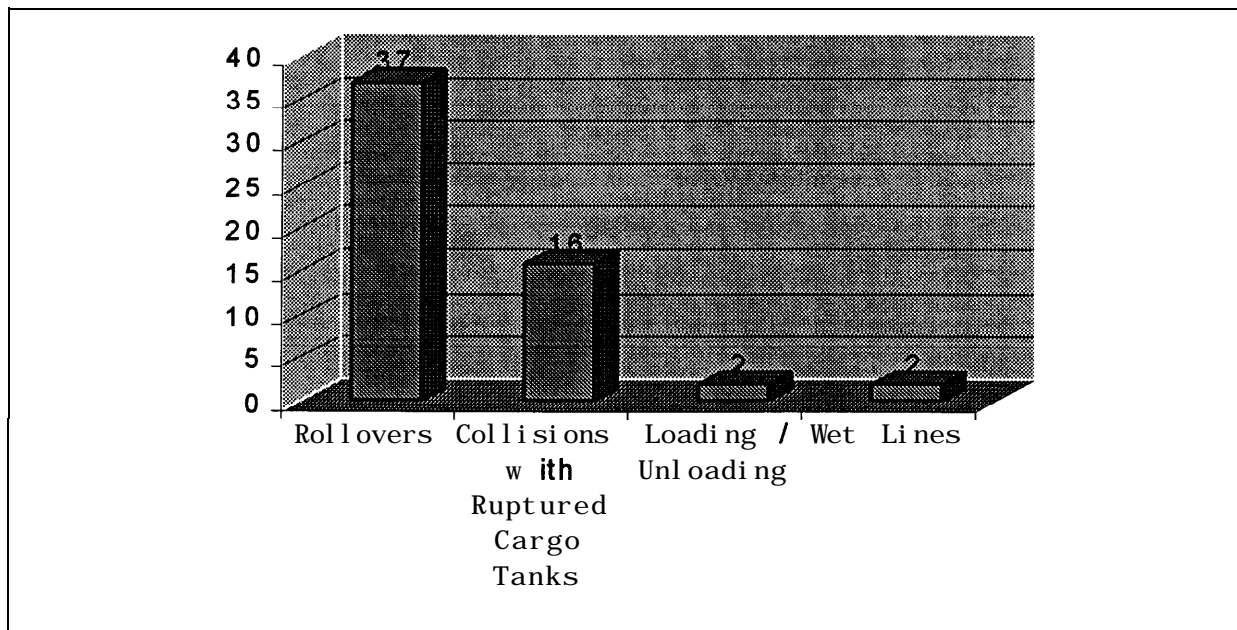
involving the release of a hazardous material during transportation. At the heart of the system is Form DOT F 5800.1. A carrier must submit this form to the DOT within 30 days of any unintentional release of a hazardous material during transportation (with certain limited exceptions, such as paint in a packaging of five gallons or less). Until October, 1998, DOT hazardous material transportation regulations and related reporting requirements applied only to interstate carriers with respect to transportation by motor vehicle; subsequent to this date regulations and reporting requirements apply to both interstate and intrastate carriers by motor vehicle. As a result, most of the information relevant to this review currently in the system is for transportation of flammable and combustible liquids by motor carriers engaged in interstate commerce. Information of this type is often adjusted by use of a multiplication factor to account for intrastate transportation. Under-reporting has been a concern -but less so for major accidents that involve fatalities or injuries. Changes to the reporting system in 1990 make information gathered since then more complete and compatible.

Appendix 3 depicts fatalities by hazard class from 1990-1997. The 57 gasoline fatalities account for over 3/4 of all fatalities for all hazardous materials in the flammable and combustible liquid hazard classes. These gasoline transportation fatalities range from 4 to 12 fatalities each year, with an average of over 7 per year. Using a factor of 1.5 to account for intrastate transportation and under reporting yields an average of 10.7 expected fatalities per year from gasoline transportation.

Looking specifically at HMIS data for gasoline transportation cargo tank motor vehicle incidents with fatalities and injuries, 91 incidents from 1990-1997 resulted in 57 fatalities, 32 major injuries, and 81 minor injuries. 37 of the fatalities involved vehicle rollovers usually accompanied by fires; 16 of the fatalities resulted from collisions with objects such as bridges, trains, or automobiles where the cargo tank ruptured; 2 resulted from loading or unloading incidents; and 2 were attributable to wet lines. The breakdown of fatalities by cause is depicted in Figure 3. The majority of persons who were killed or suffered major injuries were operators of the cargo tank motor vehicle. A single accident on March 17, 1993 in Fort Lauderdale, Florida where a tractor trailer combination was struck by an AMTRAK train accounted for 6 of the fatalities, 6 of the major injuries, and 31 of the minor injuries.

The portion of overall gasoline transportation risk that can be isolated to wet lines has the greatest relevance to this analysis. HMIS data have certain limitations when searching for

incidents involving wet lines. Reports are required only when hazardous materials are released. No information is collected on collisions, including those where wet lines may have been impacted or damaged, when a hazardous materials spill does not occur. Nor does Form DOT F 5 800.1 explicitly identify wet lines in describing packaging failure. It can usually be inferred from the description of events, the transportation phase, the amount released (limited number of gallons), combination of checked boxes (fitting/valve or hose/piping and areaaffected), and whether the spill was the result of an accident. It is not always obvious, though. The 10/09/97 incident report for Yonkers, NY, indicates no product was released and events are described only as “motorist collided with tanker.” Damage amounts of only \$11,000 are indicated even though property damage estimates are over \$7 million due to damage to an overpass. This is a more extreme example, however, and most reports more clearly indicate whether wet lines are possibly involved.

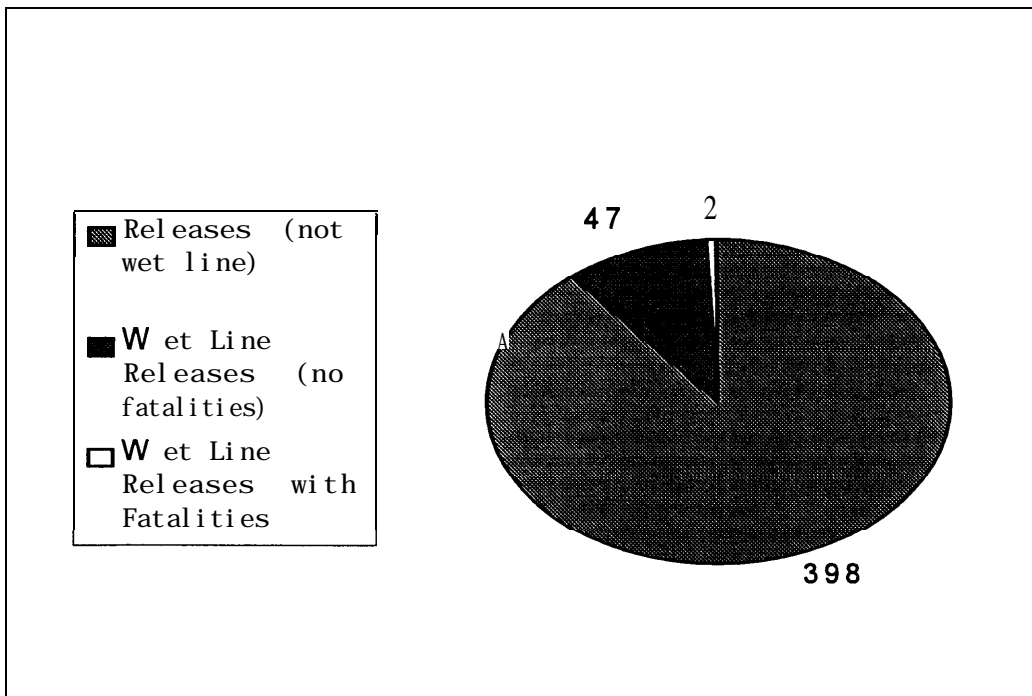


**Figure 3**  
**Fatalities for Gasoline Cargo Tank Motor Vehicle Incidents**  
**According to Cause, 1990-1997**

Another area that can present problems when evaluating risk from wet lines is the determination of the cause of fatalities and injuries. Fatalities and injuries are reported on Form DOT F 5800.1 only when they result from the hazardous materials and not from the forces of an accident or collision itself. Such a determination is not always clear cut. Furthermore, if a fatality was not reported in the Yonkers incident (if the accident were determined to be the likely cause), the incident report would contain little information to draw attention to the involvement of wet lines or the seriousness of the accident.

An **Advanced Notice of Proposed RuleMaking (ANPRM)** aimed at making changes to DOT F 5800.1 is planned. **RSPA** will be exploring changes to increase the usefulness of data collected for risk analysis and management by government and industry. Discussion items particularly relevant to wet lines are: (1) using separate forms or separate sections of the same form to gather information on bulk shipments geared to the terminology and peculiarities of particular commodities or modes, and (2) gathering information on accidents in certain instances when product may not be released. Another concept that could be pursued would be to identify on the form fatalities and injuries that may have occurred in an accident that were not believed to be directly attributable to the hazardous material. In the case of a wet lines incident, these latter data could help identify cases where ambiguity exists. In 1995, as a basis of comparison, 134 cargo tank truck motor vehicles carrying hazardous materials were involved in fatal accidents (Reference 4). Only 7 deaths were reported due to the hazardous material.

The **HMIS** data base contains records on 447 incidents involving the release of gasoline as a result of a cargo tank motor vehicle accident for the period 1990 to 1997. **RSPA** has identified 47 accidents during this period where wet lines appear to be involved. Two deaths and three major injuries resulted, and five fires occurred. Damage was estimated to be over \$800,000. Hence wet line incidents appear to constitute about 11 percent of all gasoline cargo tank motor vehicle accidents. These figures appear supportable since: (1) a significant number of the overall incidents do not involve accidents with automobiles, (2) only about 20% of accidents involve automobiles striking the side of the truck (Reference 5), and (3) not all side-on accidents of this type impact wet lines. **HMIS** data relative to wet lines are illustrated in Figure 4.



**Figure 4**  
**HMIS Gasoline Cargo Tank Incidents, 1990-1997**

Table 1 expands upon the HMIS data and shows known incidents involving wet lines for gasoline transportation by cargo tank motor vehicle from January 1, 1990 through July 31, 1998. Two incidents where a fatality to the automobile driver occurred which have been attributed to the accident or where uncertainty exists, but which might have otherwise occurred because of wet line spills and ensuing fires, are shown and considered as discussed in the analysis.

Table 1

<b>Known Wet Line Related Incidents with Fatalities or Injuries</b> <b>Flammable or Combustible Liquid Transportation</b> <b>Jan 1, 1990 - July 31, 1998</b>							
<b>Source</b>	<b>Date</b> <b>Carrier</b> <b>: Shipper</b>	<b>Location</b> <b>Commodity</b> <b>Vehicle</b> <b>Capacity</b> <b>Quantity Released</b>	<b>Fatalities</b>	<b>Major Injuries</b>	<b>Minor Injuries</b>	<b>Damages Reported by Carrier</b>	<b>Description</b>
<b>HMIS</b> <b>92081123A</b>	<b>08/13/92</b> <b>Oil Transport Co.</b> <b>Bailey Market</b>	<b>Tyler, TX</b> <b>Gasoline</b> <b>Tank Trl</b> <b>8490 Gallons</b> <b>2075 Gallons</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>\$40,000</b>	<b>Cargo transport hit in right side by vehicle which failed to stop at stop intersection. Impact crushed all loading and unloading plumbing. Impact pulled cables to open position on compartments 4 &amp; 5 releasing product.</b>
<b>API</b> <b>SWI Report</b> <b>Feb., 1994</b>  <b>(Reference 6)</b>	<b>11/22/92</b>	<b>Long Beach, CA</b> <b>Gasoline / Diesel</b> <b>MC-306</b> <b>9300 Gallons</b> <b>26 Gallons</b>	<b>1</b>	<b>0</b>	<b>0</b>		<b>The tank truck was impacted on the right side by an automobile that ran a red light. The car struck and ruptured the wet lines, releasing about 26 gallons of gasoline and diesel fuel. The fire ignited immediately. The driver of the car was killed in the accident.</b>
<b>HMIS</b> <b>94101064A</b>	<b>10/01/94</b> <b>Exxon USA</b> <b>Exxon USA</b>	<b>Houston, TX</b> <b>Gasoline</b> <b>MC-306</b>  <b>38 Gallons</b>	<b>1</b>	<b>0</b>	<b>0</b>	<b>\$55,050</b>	<b>Exxon's vehicle was struck in the intersection by an automobile. Driver/automobile was trapped and wedged under trailer. Trailer piping was sheared off and a fire broke out. 38 gallons of gasoline were contained in the sheared piping. Driver of automobile died in accident. Truck was pumped out at scene and towed.</b>
<b>HMIS</b> <b>96090310A</b>	<b>08/29/96</b> <b>Kane Transfer Co.</b> <b>Koch Fuels Inc.</b>	<b>New Germany, MN</b> <b>Gasoline</b> <b>MC-306</b> <b>8500 Gallons</b> <b>8500 Gallons</b>	<b>0</b>	<b>2</b>	<b>0</b>	<b>\$150,000</b>	<b>A pick up truck failed to stop at a stop sign and struck the tank trailer loaded with gas causing it to upset and burn. It was suggested that the vapor system and wet loading lines be studied and a better more fail safe system be designed.</b>

# Known Wet Line Related Incidents with Fatalities or Injuries

## Flammable or Combustible Liquid Transportation

Jan 1, 1990 -July 31, 1998

Source	Date Carrier Shipper	Location Commodity Vehicle Capacity Quantity Released	Fatalities	Major Injuries	Minor Injuries	Damages Reported by Carrier	Description
HMIS 97110024A	10/09/97 Mystic Bulk Carriers, Inc. Texaco, Inc.	Yonkers, NY Gasoline MC-306 9200 Gallons 0 Gallons	1	0	0	\$11,000	Motorist collided with tanker.
HMIS 98030357A	02/15/98 Star Enterprise Star Enterprise	Wilmington, DE Gasoline MC-306 9300 Gallons 20 Gallons	0 *	0	0	\$112,020	A tank truck collided with an automobile stopped on the highway. The collision caused the end portion of two product loading/unloading lines located under the cargo tank to break, resulting in the release of approximately 15-20 gallons of gasoline that were contained in the piping.
HMIS 98080276	07/07/98 Red Rock Distributing Red Rock Distributing	Mustang, OK Gasoline Tank Truck 9000 Gallons 1335 Gallons	0 *	0	0	\$100,000	Auto ran red light and struck tanker at manifold valves causing spill and fire. There is uncertainty as to whether the automobile driver died as a result of the impact in the accident or due to the fire.

\* Automobile driver killed by impact or cause of death uncertain

## **Estimated Value of Fatalities or Injuries Averted by Not Permitting Unprotected Wet Lines:**

This analysis assumes past experience can be extrapolated to the future. An average figure for the number of fatalities and injuries per year as a result of continuing to permit operation of gasoline cargo tank motor vehicles with unprotected wet lines in gasoline transportation is needed. Two fatalities and three major injuries are known from the HMIS data to be a result of wet lines during an eight year and seven month period. To this is added one known fatality that is not in the HMIS data base (possibly because it was an intrastate event). An additional fatality is added to adjust for the two fatalities which are thought to be more appropriately assessed to the accidents rather than the hazardous materials (such determinations are not always clear-cut and it is possible that a person might survive absent a fire due to wet lines). This yields 4 fatalities and 3 major injuries.

These values are then multiplied by 1.5 to allow for intrastate transportation, under reporting, and uncertainty. The end result is an estimate of 6.0 fatalities and 4.5 major injuries over an 8 year and 7 month period. The expected total average fatality rate that can be attributed to wet lines in gasoline transportation would thus be 0.70 persons per year and the average major injury rate would be 0.52 persons per year. (Note that consideration was given to not including the known fatality which is absent from the HMIS and using a factor of 2.0 instead of 1.5 to allow for intrastate transportation, under reporting, and uncertainty; however, the practical difference for this alternate approach is not significant. Fatality rates would have been the same and major injury rates would have increased by 1/3.)

These assumptions may well overstate risk due to wet lines. However, since the purpose of this analysis is to serve as a first screen for possible rulemaking or other actions, it is appropriate to use high estimates.

Using the current value of a fatality averted as \$2.8 million (OST Memorandum of March 15, 1994, updated as of 2/98) and the value of a severe injury averted as 0.1875 of the value of a fatality, a rough estimate of the economic value of fatalities and injuries that might be avoided by not permitting unprotected wet lines in gasoline transportation becomes:

$$= (\text{fatalities averted}) * (\text{value of fatality}) + (\text{major injuries averted}) * (\text{value of major injury})$$

$$= (.70 \text{ fatalities/year}) * (\$2.8 \text{ mil./fatality}) + (.52 \text{ maj. inj./year}) * (.1875 * \$2.8 \text{ mil./maj.inj.})$$

$$= \$2.2 \text{ million/year.}$$

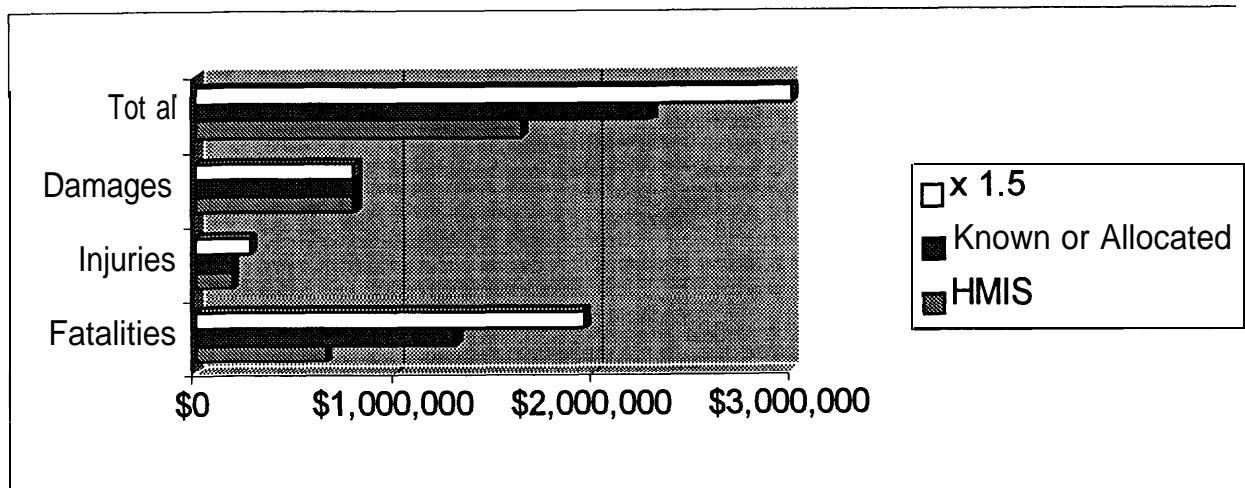
Property damage attributable to wet lines centers on the Yonkers incident with an estimated \$7 million in damage. This assumes that wet lines were the catalyst for this event, damage to the overpass would not have occurred otherwise, and this event was not an aberration. Adding damages attributed to wet lines incidents for the 1990-1997 time period yields a yearly average of about \$800,000 per year. A multiplication factor is not used to escalate property damages in the belief that the 1.5 factor for fatalities and injuries is sufficient to account for all cost categories and that a high percentage of the property damages may have occurred even if the accident had not involved wet lines.

Total Wet Line Cost Avoidance = (value of fatalities and injuries averted) + (value of damages averted)

$$\text{Total Wet Line Cost Avoidance} = (\$2.2 \text{ million}) + (\$.8 \text{ million})$$

$$= \$3.0 \text{ million per year.}$$

Value of fatalities, injuries, and damages averted are illustrated in Figure 5.



**Figure 5**  
**Value of Fatalities, Injuries, and Damages Averted**  
**Alternatives for Eliminating Wet Lines in Cargo Tank Motor Vehicles:**

**Possible options for eliminating wet lines in cargo tank motor vehicles are briefly examined below:**

#### Ton Loading of Cargo Tank Motor Vehicles

Twenty-five years ago most cargo tank motor vehicles were top loaded and the external lines were not used until delivery. Emission control requirements mandated by the EPA led to the economic decision to convert most facilities to bottom loading. Bottom loading reduces vapors and can be more easily adapted to allow for recovery of vapors during loading. Worker safety is also enhanced with bottom loading because an operator can remain on the ground and does not have to climb to the top of a truck. Dangers of static electricity in a tank are reduced because bottom loading creates less turbulence. Emission control in a top loading situation is more complex and expensive, and the cost of reverting to top loading would be prohibitive.

#### Drain Wet Lines Back to Source

Stopping pumps, closing the valve to the cargo tank, and opening a small bleed valve on the piping might allow product to drain back to the supply system in certain loading configurations. It is RSPA's understanding from prior industry comments that chances of product contamination make this solution unworkable. Metering is also a concern to industry due to the difficulty of reversing meters and accounting for product in the wet lines that is not actually supplied to the customer. This affects product accounting and gas tax collection. In addition, the potential of shifting risks of a hazardous material incident to a supply facility where the consequences might be significantly greater would have to be assessed.

#### Drain Wet Lines into Slop Tanks at Loading Facilities

While this would reduce the possibility of contamination of supply tanks, construction costs for new equipment and systems at loading facilities would be high. Of **even more** significance would be costs associated with product loss. With about 18,000,000 shipments per year, assuming product loss of even some fraction of the value of the 30-50 gallons contained in the wet lines yields an excessive annual cost. Potential loading time increases add to the total.

Additionally, any arrangement of this type will have environmental costs associated with it that must be addressed.

### Protective Guards and Shields for Wet Lines

Guards and shields add critical weight to cargo tank motor vehicle construction when used in conjunction with gasoline transportation (see sensitivities section). Designing guards that are effective in resisting the forces present in an accident would be difficult. If not carefully designed, it is possible that such devices could introduce more risk in the gasoline cargo tank motor vehicle transportation environment than they would remove. Such **add-ons** to a cargo tank motor vehicle may improve protection of wet lines while significantly increasing the potential of puncturing the aluminum cargo tank in an accident. Similarly, strengthening wet lines might better protect their contents but could defeat shear features that protect the main cargo tank compartments.

### Wet Line Design

Minimizing wet line lengths to reduce contents and attention to positioning to reduce damage may have applicability in new design, but is less practical for the large base of existing vehicles.

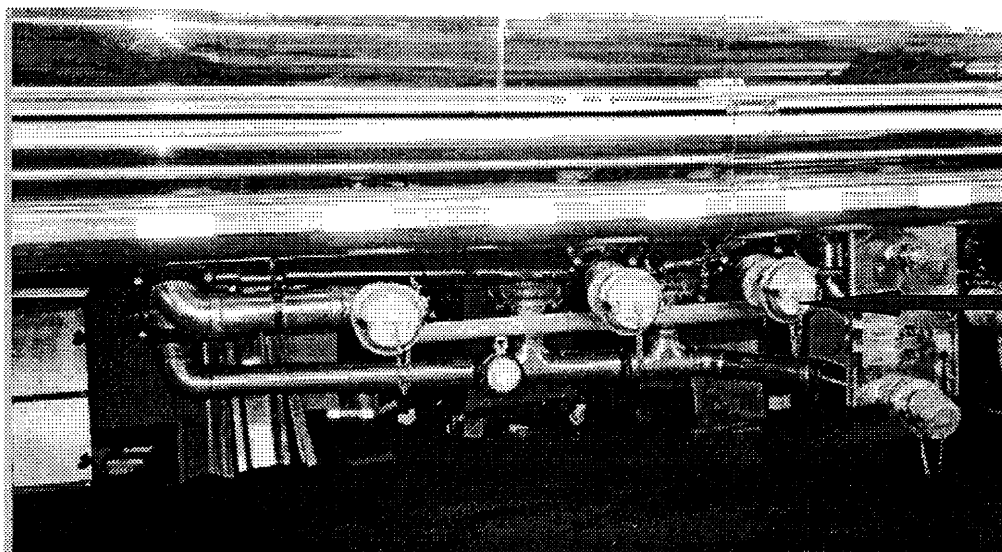
One interesting option proposed by Weld-It Company, Los Angeles, CA is adding a second set of lines that function as loading lines to individual compartments. They are placed on the lower part of the tank up from the bottom for accessibility but not high enough to be exposed to damage in case of rollover. End compartment lines are extended horizontally (each foot of 4" ID piping contains about  $\frac{2}{3}$  gallon of product) so that they terminate within the 6 foot envelope specified by API Recommended Practice 1004, "Bottom Loading and Vapor Recovery for MC-306 Tank Motor Vehicles," in order that the cargo tank motor vehicle can be loaded without movement. Since the placement is not at the tank low point, they cannot be used for unloading. The advantage of this second set of lines for loading is that they contain only approximately one gallon of gasoline each rather than the 30 to 50 gallons in the normal entire wet line configuration. Existing unloading lines would remain empty during

transportation.

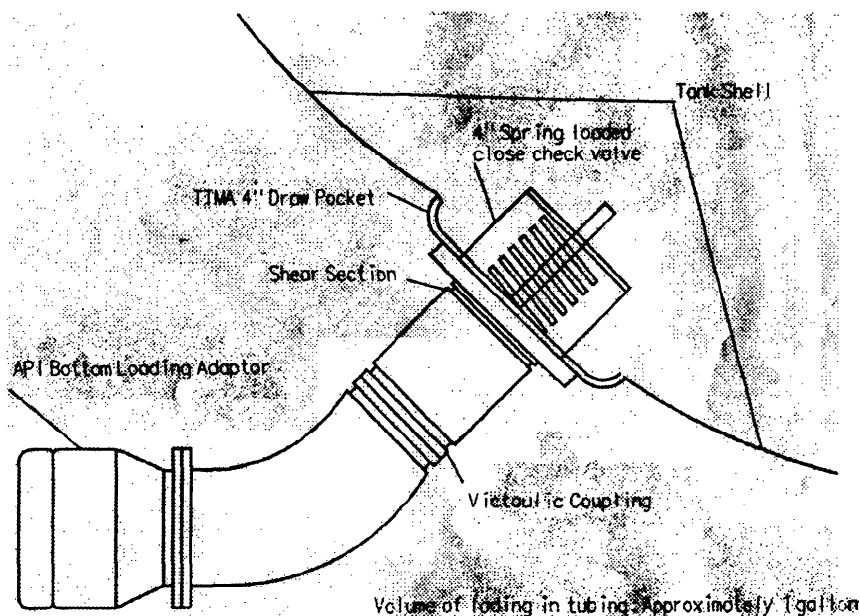
An additional concept in a dual line option (loading and unloading) applicable to new construction would be to internally place horizontal components of loading lines to minimize external elements that are exposed. The cargo tank itself is used as protection for these loading line segments in this instance.

Use of additional short, stubby loading lines is depicted in Figures 6 and 7. The cost of their addition is estimated by Weld-It to be approximately \$ 350 per compartment installed, or \$1750 for a 5 compartment cargo tank. Added weight for construction material is approximately 8 to 10 pounds per compartment or on the order of 50 pounds per vehicle.

Not all risk from wet lines is removed by use of this type of line. Limited amounts of fuel are retained in the loading line and remain after unloading. This has the practical effect of further increasing vehicle weight. It also introduces limited risk during the return segment of transportation. Horizontal components on retrofit tanks are external and contain additional fuel. It should be possible to design horizontal internal components for new construction to empty with the main cargo tank.



**Figure 6**  
**Additional**  
**Short Wet Lines**  
**for Loading**



**Figure 7**

**Schematic -- Additional  
Short Wet Lines  
for Loading**

Wet Line Purging System

An onboard pumping or purging system could be used to move product from the wet lines to a main tank compartment.

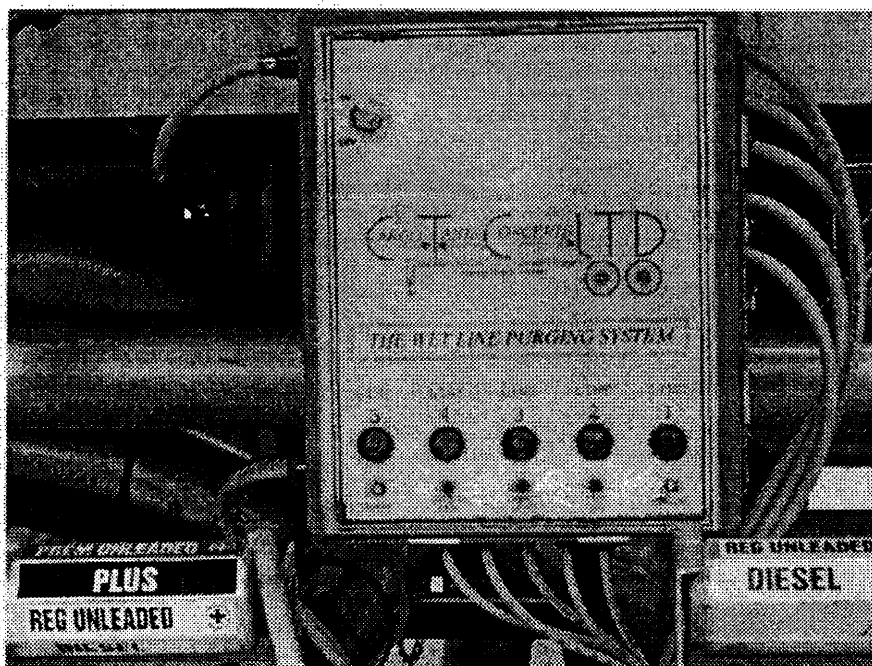
The most advanced system of which **RSPA** is aware is marketed by Cargo Tank Concepts of Brooklyn NY. Trials by one major oil company are reported to have been positive.

After loading is complete and main cargo compartment valves have been closed, the system introduces compressed air from an auxiliary tank through an air filter and regulator into the wet lines. Compressed air flows into the lines under low pressure (.5 psi above atmospheric) and at a low flow rate (.5 cubic feet per minute). Air flows were small enough and rates low enough that static electricity is not believed to be a problem. Product in the wet lines flows through product purging lines through a check valve into the tank compartments. The purging process takes about 6 minutes. A control box automatically directs functions so that time is not added to the loading operation.

Optical sensors detect product in the wet lines and time-out features alert operators to

potential problems. One ancillary benefit from a safety perspective that occurred in system trials and early installations was detection of a leaking main cargo tank valve in a high percentage of cargo tank motor vehicles.

Cost is roughly \$5000 for a cargo tank motor vehicle, and one hundred pounds of weight are added to the vehicle. The control box of the wet line purging system is shown in Figure 8. The major oil company will have installed a number of units at two terminals by the end of 1998. According to Cargo Tank Concepts, the oil company plans to equip a major portion of its company-owned fleet with the system over a 3 year period.



**Figure 8**

**Control Box – Wet  
Line Purging System**

### Other Design Changes

A number of the wet line incidents examined as part of this analysis involved substantial loss of lading from the cargo tanks. Whether this was the result of damage incurred in the accidents or the result of leaking main cargo tank valves is often unclear. In the case of the former, design changes to cable routing (used in about 2/3 of MC 306 / 406 cargo tank motor vehicles, Reference 6) that controls the internal valves might help avoid or minimize this problem. Sight

glasses in unloading lines might similarly facilitate procedures to periodically verify the integrity of the internal valves. While these changes would not eliminate the dangers inherent with wet lines, they would help abate these dangers or, if wet lines were eliminated, reduce other dangers.

### **Cost Analysis:**

The two most advanced options for eliminating wet line risks in gasoline transportation that are being marketed are (1) wet line purging systems and (2) alternative short loading lines.

Assuming for new construction that installed costs on the wet line purging system could be brought down to the \$2500 per vehicle level, mandating such devices on a 50,000 base of cargo tank vehicles would result in a one time cost of about \$ 125,000,000 if applied to all vehicles at one time. Costs for retrofitting purging systems to existing vehicles are estimated at \$3,500 per truck. Both scenarios would occur over a period of time, however. In the case of new construction, the span is estimated to be over the 30 year estimated useful life of the cargo tank motor vehicle. Retrofit is estimated to occur over 5 years. Benefits accrue over the useful life of the vehicle. Annual maintenance costs are estimated at 5% of the original cost based on the relative complexity of the electrical and mechanical components of the system (and are based on new system costs for both the new system and retrofit cases).

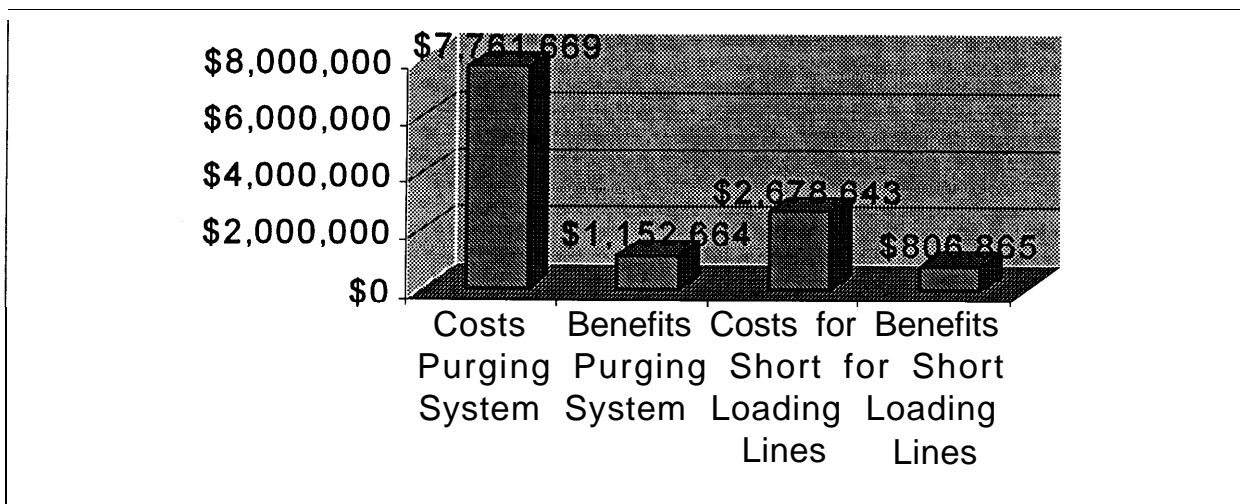
Assuming installed cost of alternative short loading lines is approximately \$1400 per vehicle (\$350 per tank compartment times an average of 4 compartments per cargo tank motor vehicle), mandating such devices on a 50,000 base of cargo tank motor vehicles would result in a one time cost of \$70,000,000 if applied to all vehicles at one time. Retrofitting costs would be similar; however, benefits would be lower because of additional retained fuel. Adjustment of the benefits of the calculated amount to 90% for the new construction case and 70% for the retrofit case might be appropriate to account for the fact that not all wet line risk is eliminated with this option. Annual maintenance costs are estimated at 1% of the original cost.

Vehicle weight is a critical aspect in gasoline transportation. States typically restrict vehicle weight to the 80,000 pound range. Adding 50 pounds of weight in equipment to purge or

protect wet lines means about 8 gallons of fuel cannot be carried. This translates to 144,000,000 gallons (8 gallons times 18,000,000 shipments per year) of fuel requiring an additional 18,000 shipments in the typical 8000 gallon cargo tank motor vehicles annually. An average of 30 miles per shipment results in 540,000 additional truck miles per year, with additional costs and accident risks associated with these shipments. Valuing these additional miles at \$1 per mile to account for vehicle and operator costs would add \$ .54 million in annual costs to a system adding 50 pounds of weight or \$ 1.08 million in annual cost to a system adding 100 pounds.

The added transportation risk using a large or medium truck fatality rate of 2.8 deaths (truck and other motor vehicle occupants and nonmotorists) per 100 million miles results in a traffic accident fatality increase of 0.015 fatalities per year in the case of an additional 50 pounds of added weight or 0.030 fatalities per year for an additional 100 pounds of weight. These are considered negligible for the purposes of this analysis.

Figure 9 compares the present value of costs and benefits on an average annual basis for retrofitting purging systems or short loading lines. Table 2 summarizes estimated costs and risk avoidance by options. Both include investment, maintenance and repair, and weight penalties costs.



**Figure 9**  
**Present Value on an Average Annual Basis for Costs and Benefits for Retrofitting**  
**Purging Systems or Short Loading Lines**

**Table 2 - Estimated Costs and Risk Avoidance Benefits by Option**

	<i>Over 30 Year Useful Life</i>	<b>Purging System New Construction</b>	<b>Purging System Retrofit</b>	<b>Short Loading Lines New Construction</b>	<b>Short Loading Lines Retrofit</b>
A	<b>Unit Installation Cost</b>	\$2,500	\$3,500	\$1,400	\$1,400
B	<b>Present Value (per unit, per year) of <u>Installation Cost</u></b>	\$37	\$99	\$21	\$40
C	<b>Present Value (per unit, per year) of <u>Maintenance Cost</u></b>	\$20	\$48	\$2	\$5
D	<b>Present Value (per unit, per year) of <u>Weight Penalty Cost</u> (Note 1)</b>	\$4	\$8	\$4	\$9
E	<b>Present Value (per unit, per year) of <u>Total Annual Costs</u></b>	\$61	\$155	\$27	\$54
F	<b>Present Value (per unit, per year) of <u>Benefits</u></b>	\$10	\$23	\$9	\$16
G	<b><u>Benefit/Cost Ratio</u></b>	0.16	0.15	0.33	0.30

Note 1: Weight penalty cost is the value of additional miles to move equivalent quantities of fuel because of the weight of the installed systems. Additional weight is estimated at 100 pounds for the wet line purging systems, 77 pounds for short loading line system for new construction (50 pounds plus 27 pounds for retained fuel), and 104 pounds for the short loading line system for retrofit (50 pounds plus 54 pounds for retained fuel). New system short lines are estimated to contain 1 gallon in each of four lines, or 4 gallons of product weighing 27 pounds. Retrofit systems are estimated to contain an additional 6 feet of horizontal piping containing and additional 4 gallons of fuel weighing another 27 pounds.

Appendix 4 provides a more detailed breakout of cost and benefit figures, and serves as the basis for Figure 9 and Table 2. Base case analysis of options in Appendix 3 use a real discount rate of 7% in accordance with OMB Circular No. A-94 (Reference 7). An alternate case analysis was also done using a real discount rate of 3.5% to try to more closely approximate an inflation adjusted view of the value of capital based rather than an investment decision approach. The most favorable alternate case analysis from a benefits to cost ratio is included; however, they did not differ significantly from those of the base case.

Application of requirements during new construction reduces costs in the case of the wet line purging system and allows **a more** full appreciation of benefits in the short loading line option. In general, deferring costs results in lower costs and better benefit to cost ratios; it also defers and lower benefits. Even in the most favorable option (short loading lines in new construction), costs exceed benefits by a factor of about 3 to 1.

The cost to eliminate wet lines in gasoline transportation would add less than 1 /100 of one cent to the price of gasoline. The average bill would be a few cents a year to each American consumer. Nevertheless, when the present value of all costs are considered, the impact of regulations to eliminate wet lines in gasoline transportation would likely approach 100 million dollars over the life of any system for this purpose.

### **Sensitivities and Uncertainties:**

Assumptions for annual fatality, injury, and damage risks pertaining to wet lines in gasoline transportation used in this analysis are such that estimates may be on the high side or worst case. However, fatalities to date have involved automobiles with single occupants. Multiple occupants or families involved in such incidents would likely push numbers higher. On the other hand, using only known fatalities and injuries attributable to wet lines and known estimates of damages would result in average annual cost avoidance or benefits of less than \$2.0 million (which would be further reduced if the overpass damages in the Yonkers fatality were considered unrepresentative), or about 2/3 of the figure used in this analysis. Southwest Research Institute (Reference 6) estimates the fatality rate due to wet lines at about one every eleven years. They also state, without elaboration, that based on further information that the fatality rate could be as high as 1.5 per year. Estimates developed and used in this analysis fall

in the middle of that range.

Any solution that adds operating time to either the loading or unloading process will be difficult to justify. With roughly 18,000,000 shipments per year, even a solution that adds operating time with a value of over 25 cents per shipment results in an annual cost of \$4,500,000, which exceeds the estimated annual value of fatalities, injuries, and damages that might be avoided.

A unit cost of about \$600 per cargo tank truck motor vehicle that eliminates the wet line risk approaches the range where consideration is justified based on a strict interpretation of benefit and cost guidelines -- provided other costs do not increase and risks are not shifted.

This analysis does not consider costs of environmental damage. Nor does it consider the costs of litigation, evacuations, or closures. A draft risk assessment (Reference 8) prepared for the Office of Motor Carriers, Federal Highway Administration, examining the impacts of Class 3 (flammable and combustible liquids) hazardous material incidents, estimates the impact directly related to the hazardous material cargo to be apportioned approximately 40% to fatality and injury cost and 60% to delay, evacuation, cleanup, product loss, carrier damage, property damage, and environmental damage costs. A factor of 2.5 could have been applied to wet line fatality and injury costs to estimate other impacts of wet lines; however, a substantial portion of these impacts are caused by the very fact that an accident with a cargo tank motor vehicle carrying gasoline has occurred and would result whether loading and unloading lines contained fuel or not. A doubling of the fatality and injury cost to account for other effects, rather than using carrier reported damage amounts and the \$7 million to rebuild an overpass in the Yonkers, NY, incident would result in a cost avoidance value from prohibiting wet lines of \$ 4.4 million per year.

The analysis calculates a weight penalty with the assumption that there would always be a displacement of fuel with added equipment weight. This may not be a factor when vehicles do not approach highway weight limits or when they are not fully loaded. Perhaps this penalty should have been applied to only one-half or three-quarters of the vehicles. This approach would yield a benefit to cost ratio of 0.35 rather than 0.33 in the most favorable option from this standpoint.

It is conceivable that added systems or loading lines might pose risks apart from those they are intended to eliminate. For instance, additional loading lines provide additional tank openings that might be affected in rollovers or collisions. We assume these lines can be located and protected such that any added risks of a different nature are negligible; however, there is a degree of uncertainty in this conclusion and benefits could be partially offset if these risks prove other than theoretical.

Wet line incidents (and resultant fire from the loss of fuel in this segment) could function as a catalyst for larger cargo tank **fires** (where ignition would not have **otherwise** occurred) where there is loss of life or major injury. This is a difficult scenario to detect and might be masked in the incident reports and overall statistics. The immediate hazard zone due to a pool **fire** for a spill of 50 gallons of gasoline from wet lines is illustrated in Appendix 5. The heat content of this amount of fuel is unlikely to cause an explosion of the tank contents; however, burn through of the aluminum tank above the liquid line is a possibility. A leaking main cargo valve (preexisting or caused by the accident) or other leaking due to cargo tank damage caused by the accident could enhance any **fire** which may not have occurred absent a release of fuel from the wet lines. The 10/09/97 Yonkers, NY, incident may fall in this category. If this situation is routine rather than atypical, the benefits of prohibiting unprotected wet lines in gasoline transportation could be significantly greater.

## **Conclusion:**

A determination of the proper course of action based on the risk from wet lines and the costs to correct problems is in a **grey** area, particularly considering the uncertainties inherent in examination of a probabilistic case where data are sometimes deficient. Risks are high enough to warrant attention, but costs that would be incurred to eliminate wet lines or mitigate the hazards are such that general benefit and cost guidelines are exceeded.

Solutions that apply to new construction or occur at major overhauls of cargo tank motor vehicles may have the most merit. Costs are minimized and risks are reduced gradually -- but since risks are already at a relatively low level this tradeoff may be appropriate. Production of new cargo tank motor vehicles for flammable liquids is less than 2000 per year. Hydrostatic pressure testing and internal visual inspections are required every 5 years on MC

306 and DOT 406 cargo tank motor vehicles and might offer one time frame to consider modifications required by regulation.

Prohibition of wet lines in certain high risk environments, such as high traffic or accident rate areas, may be particularly beneficial while such a course may represent good practices in a general sense.

### **Possible Future Actions:**

Three possible future courses of action, based on the level of risk of wet lines in the transportation of flammable and combustible liquids and the costs to eliminate these risks, are described below:

- (1) Decide that risk and cost / benefits do not conclusively point to action, but are in a range that rulemaking is in order. Such a course would help better **define** risks and costs and formally take into account input of affected parties in industry and the public.
- (2) Defer a decision at this time. **Publicize** and closely monitor and evaluate trials or early industry installations of systems aimed at eliminating wet line problems. Sponsor research, preferably in partnership with industry, aimed at developing concepts. Actively work with cargo tank motor vehicle manufacturers to better determine what might be possible in the way of increasing protection for wet lines and reducing dangers in an accident. Gather better data on wet line incidents. Reevaluate the state of progress at the end of 24 months.
- (3) Determine that wet line risks and costs for corrective action do not warrant regulatory action.

## Appendix 1

### Motor Gasoline Distribution Data

Source: Hazardous Materials Shipments  
DOT/RSPA/OHMS August, 1998 (Reference 3)

Finished Motor Gasoline Consumption:                      **7,891,000** Barrels/Day  
   **331,422,000** Gallons/Day  
   **120,969,030,000** Gallons/Year

Distribution:

By Oil Co.	54%: regional storage (RS) to retail outlets (Outlets) in <i>nominal</i> 8000 gallon trucks =	22,371 shipments/day
By Jobber	46%:	
	50% RS to Outlets in 8000 gallon tanks=	9,528 shipments/day
	25% RS to jobber storage in 8000 gallon trucks, reshipment to Outlets in 8000 gallon trucks=	9,528 shipments/day
	25% RS to jobber storage in 8000 gallon trucks, reshipment to Outlets in 2000 gallon trucks=	23,821 shipments/day

Gallons per day reshipped in 8000 gallon trucks:	38,113,530
Gallons per day reshipped in 2000 gallon trucks:	38,113,530

	<u>Daily Shipments</u>	<u>% of Daily Shipments</u>
Total gallons per day shipped in 8000 gallon trucks:	369,535,530	46,192
Total gallons per day shipped in 2000 gallon trucks:	38,113,530	19,057
Total:	407,649,060	65,249

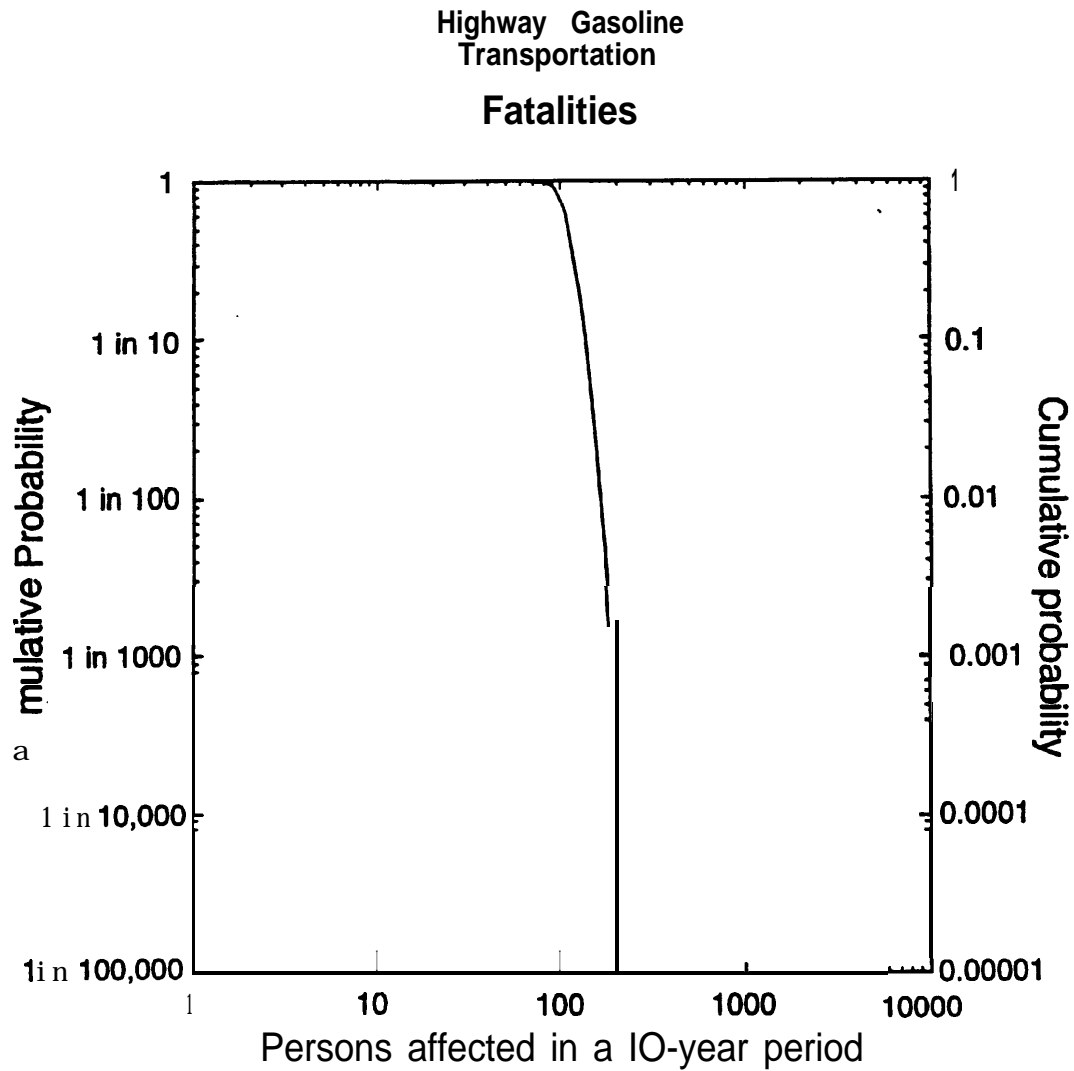
% of Daily Gasoline Consumption Reshipped =	23
% of Daily Gasoline Consumption Reshipped in 2000 Gallons Trucks =	12

Number of 8000 gallon truck required to accommodate consumption*:	15,397
Number of 2000 gallon truck required to accommodate consumption*:	6,352
Total:	21,750

\*assumes each truck makes 3 trips per day

## Appendix 2

Source: Reference 9



Probability of fatalities resulting from highway transportation of gasoline for a 10-year period.

## Appendix 2 (continued)

Probability of fatalities resulting from highway transportation of gasoline for a 10-year period. Average fatality statistics are also listed,

Fatalities	Probability	Fatalities	Probability
60	I > 0.995 I	140	1 0.049
70	I 0.99 I	150	0.019
80	I 0.95 I	160	I 0.0070 I
90	I 0.83 I	170	I 0.0024 I
100	I 0.64 I	180	I 0.00077 I
110	I 0.41 I	190	I 0.00024 I
120	I 0.23 I	200	I 6.7E-05 I
130	I 0.11 I	220	I <1.0E-06 I
Median number of fatalities			106
Average number of fatalities			108
Average number of fatalities per $10^6$ ton miles			0.00063

## Appendix 3

### Hazardous Materials Incidents, 1990-1997 Fatalities by Hazard Class / Hazardous Material

Hazard Class Hazardous Material	Number of Fatalities								Total
	1990	1991	1992	1993	1994	1995	1996	1997	
<b>Combustible Liquid</b>	<b>3</b>	<b>2</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>2</b>	<b>0</b>	<b>7</b>
Combustible Liquid n.o.s.	3	...	...	...	...	...	...	...	3
Fuel Oil No.1,2,4,5,6	...	2	...	...	...	...	1	...	3
Petroleum Distillate	...	...	...	...	...	...	1	...	1
<b>Flammable Gas</b>	<b>0</b>	<b>0</b>	<b>3</b>	<b>0</b>	<b>1</b>	<b>2</b>	<b>0</b>	<b>3</b>	<b>9</b>
Acetylene Dissolved	...	...	...	...	1	...	...	...	1
Petroleum Gases Liquefied	...	...	3	...	...	2	...	3	6
<b>Poisonous Gas</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>2</b>	<b>0</b>	<b>2</b>
Ammonia Anhydrous	...	...	...	...	...	...	1	...	1
Chlorine	...	...	...	...	...	...	1	...	1
<b>Flammable - Combustible Liquid</b>	<b>5</b>	<b>8</b>	<b>12</b>	<b>15</b>	<b>9</b>	<b>5</b>	<b>6</b>	<b>8</b>	<b>68</b>
Alcohol n.o.s.	...	...	...	...	...	...	...	...	1
Asphalt	...	...	...	1	...	...	...	...	1
Denatured Alcohol	...	...	...	1	1	...	...	...	2
Flammable Liquid n.o.s.	...	...	...	...	...	...	1	1	2
Fuel Aviation Turbine	...	...	1	1	...	...	...	...	2
Gasoline	4	6	10	12	9	4	4	6	57
Hydrocarbons Liquid n.o.s.	...	...	...	...	...	...	1	...	1
Paint	1	...	...	...	...	...	...	...	1
Paint Related Material	...	...	...	...	1	1	...	...	1
Petroleum Crude Oil	...	...	1	...	...	...	...	...	1
<b>Oxidizer</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>110</b>	<b>0</b>	<b>110</b>
Oxidizing Solid n.o.s.	...	...	...	...	...	...	110	...	110
<b>Miscellaneous Hazardous</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1</b>
Elevated Temp Material Liquid	...	...	...	...	1	...	...	...	1
-Total	<b>8</b>	<b>10</b>	<b>15</b>	<b>15</b>	<b>11</b>	<b>7</b>	<b>120</b>	<b>11</b>	<b>197</b>

## Appendix 4 -- Present Value Analysis

### Base Case Present Value of Benefits and Costs *Purging System, New Construction Option*

Real Discount Rate = 7.00%

<u>Year</u>	<u>Installation</u>	<u>Maintenance</u>	<u>Weight</u>		<u>Discount</u>	<u>Present</u>	<u>Present</u>
	<u>Cost</u>	<u>Cost</u>	<u>Penalty</u>	<u>Benefit</u>	<u>Factor</u>	<u>Value</u>	<u>Value</u>
			<u>Cost</u>			<u>Costs</u>	<u>Benefit</u>
1	\$4,166,667	208,333	\$36,000	\$100,000	0.9662	\$4,261,836	\$96,618
2	\$4,166,667	416,667	\$72,000	\$200,000	0.9030	\$4,203,651	\$180,595
3	\$4,166,667	625,000	\$108,000	\$300,000	0.8439	\$4,134,839	\$253,171
4	\$4,166,667	833,333	\$144,000	\$400,000	0.7887	\$4,057,040	\$315,477
5	\$4,166,667	1,041,667	\$180,000	\$500,000	0.7371	\$3,971,723	\$368,548
6	\$4,166,667	1,250,000	\$216,000	\$600,000	0.6889	\$3,880,206	\$413,325
7	\$4,166,667	1,458,333	\$252,000	\$700,000	0.6438	\$3,783,665	\$450,666
8	\$4,166,667	1,666,667	\$288,000	\$800,000	0.6438	\$3,940,969	\$515,047
9	\$4,166,667	1,875,000	\$324,000	\$900,000	0.6017	\$3,830,162	\$541,522
10	\$4,166,667	2,083,333	\$360,000	\$1,000,000	0.5623	\$3,716,986	\$562,328
11	\$4,166,667	2,291,667	\$396,000	\$1,100,000	0.5255	\$3,602,225	\$578,094
12	\$4,166,667	2,500,000	\$432,000	\$1,200,000	0.4912	\$3,486,572	\$589,390
13	\$4,166,667	2,708,333	\$468,000	\$1,300,000	0.4590	\$3,370,634	\$596,735
14	\$4,166,667	2,916,667	\$504,000	\$1,400,000	0.4290	\$3,254,944	\$600,596
15	\$4,166,667	3,125,000	\$540,000	\$1,500,000	0.4009	\$3,139,964	\$601,398
16	\$4,166,667	3,333,333	\$576,000	\$1,600,000	0.3747	\$3,026,099	\$599,524
17	\$4,166,667	3,541,667	\$612,000	\$1,700,000	0.3502	\$2,913,692	\$595,322
18	\$4,166,667	3,750,000	\$648,000	\$1,800,000	0.3273	\$2,803,042	\$589,104
19	\$4,166,667	3,958,333	\$684,000	\$1,900,000	0.3059	\$2,694,400	\$581,151
20	\$4,166,667	4,166,667	\$720,000	\$2,000,000	0.2859	\$2,587,976	\$571,718
21	\$4,166,667	4,375,000	\$756,000	\$2,100,000	0.2672	\$2,483,944	\$561,031
22	\$4,166,667	4,583,333	\$792,000	\$2,200,000	0.2497	\$2,382,448	\$549,296
23	\$4,166,667	4,791,667	\$828,000	\$2,300,000	0.2333	\$2,283,602	\$536,696
24	\$4,166,667	5,000,000	\$864,000	\$2,400,000	0.2181	\$2,187,491	\$523,393
25	\$4,166,667	5,208,333	\$900,000	\$2,500,000	0.2038	\$2,094,183	\$509,534
26	\$4,166,667	5,416,667	\$936,000	\$2,600,000	0.1905	\$2,003,721	\$495,248
27	\$4,166,667	5,625,000	\$972,000	\$2,700,000	0.1780	\$1,916,132	\$480,650
28	\$4,166,667	5,833,333	\$1,008,000	\$2,800,000	0.1664	\$1,831,428	\$465,843
29	\$4,166,667	6,041,667	\$1,044,000	\$2,900,000	0.1555	\$1,749,606	\$450,916
30	\$4,166,667	6,250,000	\$1,080,000	\$3,000,000	0.1453	\$1,670,651	\$435,948

**Total: \$91,263,832 \$14,608,884**

**Benefit/Cost Ratio: 0.16**

Analysis assumes all benefits and costs accrue at middle of year.

**Base Case Present Value of Benefits and Costs**  
***Purging Sys tern, Retrofit Option***

Real Discount Rate = 7.00%

<u>Year</u>	<u>Installation</u> <u>cost</u>	<u>Maintenance</u> <u>cost</u>	<u>Weight</u> <u>Penalty</u> <u>cost</u>	<u>Benefit</u>	<u>Discount</u> <u>Factor</u>	<u>Present</u> <u>Value</u> <u>costs</u>	<u>Present</u> <u>Value</u> <u>Benefit</u>
1	\$35,000,000	\$1,250,000	\$216,000	\$600,000	0.9662	\$35,232,850	\$579,710
2	\$35,000,000	\$2,500,000	\$432,000	\$1,200,000	0.9030	\$34,251,659	\$1,083,570
3	\$35,000,000	\$3,750,000	\$648,000	\$1,800,000	0.8439	\$33,248,057	\$1,519,024
4	\$35,000,000	\$5,000,000	\$864,000	\$2,400,000	0.7887	\$32,229,175	\$1,892,865
5	\$35,000,000	\$6,250,000	\$1,080,000	\$3,000,000	0.7371	\$31,201,309	\$2,211,290
6		\$6,250,000	\$1,080,000	\$3,000,000	0.6889	\$5,049,458	\$2,066,627
7		\$6,250,000	\$1,080,000	\$3,000,000	0.6438	\$4,719,119	\$1,931,427
8		\$6,250,000	\$1,080,000	\$3,000,000	0.6438	\$4,719,119	\$1,931,427
9		\$6,250,000	\$1,080,000	\$3,000,000	0.6017	\$4,410,392	\$1,805,072
10		\$6,250,000	\$1,080,000	\$3,000,000	0.5623	\$4,121,862	\$1,686,983
11		\$6,250,000	\$1,080,000	\$3,000,000	0.5255	\$3,852,207	\$1,576,620
12		\$6,250,000	\$1,080,000	\$3,000,000	0.4912	\$3,600,194	\$1,473,476
13		\$6,250,000	\$1,080,000	\$3,000,000	0.4590	\$3,364,667	\$1,377,081
14		\$6,250,000	\$1,080,000	\$3,000,000	0.4290	\$3,144,548	\$1,286,991
15		\$6,250,000	\$1,080,000	\$3,000,000	0.4009	\$2,938,830	\$1,202,796
16		\$6,250,000	\$1,080,000	\$3,000,000	0.3747	\$2,746,570	\$1,124,108
17		\$6,250,000	\$1,080,000	\$3,000,000	0.3502	\$2,566,888	\$1,050,568
18		\$6,250,000	\$1,080,000	\$3,000,000	0.3273	\$2,398,961	\$981,839
19		\$6,250,000	\$1,080,000	\$3,000,000	0.3059	\$2,242,020	\$917,607
20		\$6,250,000	\$1,080,000	\$3,000,000	0.2859	\$2,095,345	\$857,577
21		\$6,250,000	\$1,080,000	\$3,000,000	0.2672	\$1,958,267	\$801,473
22		\$6,250,000	\$1,080,000	\$3,000,000	0.2497	\$1,830,156	\$749,041
23		\$6,250,000	\$1,080,000	\$3,000,000	0.2333	\$1,710,426	\$700,038
24		\$6,250,000	\$1,080,000	\$3,000,000	0.2181	\$1,598,529	\$654,241
25		\$6,250,000	\$1,080,000	\$3,000,000	0.2038	\$1,493,952	\$611,440
26		\$6,250,000	\$1,080,000	\$3,000,000	0.1905	\$1,396,217	\$571,439
27		\$6,250,000	\$1,080,000	\$3,000,000	0.1780	\$1,304,876	\$534,056
28		\$6,250,000	\$1,080,000	\$3,000,000	0.1664	\$1,219,510	\$499,117
29		\$6,250,000	\$1,080,000	\$3,000,000	0.1555	\$1,139,729	\$466,465
30		\$6,250,000	\$1,080,000	\$3,000,000	0.1453	\$1,065,167	\$435,948
<b>Total:</b>						<b>\$232,850,060</b>	<b>\$34,579,915</b>

**Benefit/Cost Ratio: 0.15**

Analysis assumes all benefits and costs accrue at middle of year.

**Base Case Present Value of Benefits and Costs**  
**Short Loading Lines, New Construction Option**

Real Discount Rate = 7.00%

<u>Year</u>	<u>Installation Cost</u>	<u>Maintenance Cost</u>	<u>Weight Penalty cost</u>	<u>[90%] Benefit</u>	<u>Discount Factor</u>	<u>Present Value costs</u>	<u>Present Value Benefit</u>
1	\$2,333,333	23,333	\$37,440	\$90,000	0.9662	\$2,313,147	\$86,957
2	\$2,333,333	46,667	\$74,880	\$180,000	0.9030	\$2,216,696	\$162,536
3	\$2,333,333	70,000	\$112,320	\$270,000	0.8439	\$2,122,965	\$227,854
4	\$2,333,333	93,333	\$149,760	\$360,000	0.7887	\$2,032,011	\$283,930
5	\$2,333,333	116,667	\$187,200	\$450,000	0.7371	\$1,943,872	\$331,694
6	\$2,333,333	140,000	\$224,640	\$540,000	0.6889	\$1,858,568	\$371,993
7	\$2,333,333	163,333	\$262,080	\$630,000	0.6438	\$1,776,106	\$405,600
8	\$2,333,333	186,667	\$299,520	\$720,000	0.6438	\$1,815,232	\$463,542
9	\$2,333,333	210,000	\$336,960	\$810,000	0.6017	\$1,733,045	\$487,369
10	\$2,333,333	233,333	\$374,400	\$900,000	0.5623	\$1,653,843	\$506,095
11	\$2,333,333	256,667	\$411,840	\$990,000	0.5255	\$1,577,587	\$520,284
12	\$2,333,333	280,000	\$449,280	\$1,080,000	0.4912	\$1,504,229	\$530,451
13	\$2,333,333	303,333	\$486,720	\$1,170,000	0.4590	\$1,433,718	\$537,061
14	\$2,333,333	326,667	\$524,160	\$1,260,000	0.4290	\$1,365,995	\$540,536
15	\$2,333,333	350,000	\$561,600	\$1,350,000	0.4009	\$1,300,997	\$541,258
16	\$2,333,333	373,333	\$599,040	\$1,440,000	0.3747	\$1,238,657	\$539,572
17	\$2,333,333	396,667	\$636,480	\$1,530,000	0.3502	\$1,178,906	\$535,790
18	\$2,333,333	420,000	\$673,920	\$1,620,000	0.3273	\$1,121,671	\$530,193
19	\$2,333,333	443,333	\$711,360	\$1,710,000	0.3059	\$1,066,879	\$523,036
20	\$2,333,333	466,667	\$748,800	\$1,800,000	0.2859	\$1,014,456	\$514,546
21	\$2,333,333	490,000	\$786,240	\$1,890,000	0.2672	\$964,326	\$504,928
22	\$2,333,333	513,333	\$823,680	\$1,980,000	0.2497	\$916,413	\$494,367
23	\$2,333,333	536,667	\$861,120	\$2,070,000	0.2333	\$870,642	\$483,026
24	\$2,333,333	560,000	\$898,560	\$2,160,000	0.2181	\$826,937	\$471,054
25	\$2,333,333	583,333	\$936,000	\$2,250,000	0.2038	\$785,225	\$458,580
26	\$2,333,333	606,667	\$973,440	\$2,340,000	0.1905	\$745,431	\$445,723
27	\$2,333,333	630,000	\$1,010,880	\$2,430,000	0.1780	\$707,484	\$432,585
28	\$2,333,333	653,333	\$1,048,320	\$2,520,000	0.1664	\$671,311	\$419,259
29	\$2,333,333	676,667	\$1,085,760	\$2,610,000	0.1555	\$636,843	\$405,824
30	\$2,333,333	700,000	\$1,123,200	\$2,700,000	0.1453	\$604,011	\$392,354

**Total: \$39,997,203 \$13,147,996**

**Benefit/Cost Ratio: 0.33**

Analysis assumes all benefits and costs accrue at middle of year.

**Base Case Present Value of Benefits and Costs**  
**Short Loading Lines, Retrofit Option**

Real Discount Rate = 7.00%

<u>Year</u>	<u>Installation</u> <u>cost</u>	<u>Maintenance</u> <u>cost</u>	<u>Weight</u> <u>Penalty</u> <u>Cost</u>	<u>[70%]</u> <u>Benefit</u>	<u>Discount</u> <u>Factor</u>	<u>Present</u> <u>Value</u> <u>costs</u>	<u>Present</u> <u>Value</u> <u>Benefit</u>
1	\$14,000,000	\$140,000	\$224,640	\$420,000	0.9662	\$13,878,879	\$405,797
2	\$14,000,000	\$280,000	\$449,280	\$840,000	0.9030	\$13,300,176	\$758,499
3	\$14,000,000	\$420,000	\$673,920	\$1,260,000	0.8439	\$12,737,792	\$1,063,317
4	\$14,000,000	\$560,000	\$898,560	\$1,680,000	0.7887	\$12,192,067	\$1,325,005
5	\$14,000,000	\$700,000	\$1,123,200	\$2,100,000	0.7371	\$11,663,230	\$1,547,903
6		\$700,000	\$1,123,200	\$2,100,000	0.6889	\$1,255,958	\$1,446,639
7		\$700,000	\$1,123,200	\$2,100,000	0.6438	\$1,173,792	\$1,351,999
8		\$700,000	\$1,123,200	\$2,100,000	0.6438	\$1,173,792	\$1,351,999
9		\$700,000	\$1,123,200	\$2,100,000	0.6017	\$1,097,002	\$1,263,550
10		\$700,000	\$1,123,200	\$2,100,000	0.5623	\$1,025,236	\$1,180,888
11		\$700,000	\$1,123,200	\$2,100,000	0.5255	\$958,164	\$1,103,634
12		\$700,000	\$1,123,200	\$2,100,000	0.4912	\$895,481	\$1,031,433
13		\$700,000	\$1,123,200	\$2,100,000	0.4590	\$836,898	\$963,956
14		\$700,000	\$1,123,200	\$2,100,000	0.4290	\$782,147	\$900,894
15		\$700,000	\$1,123,200	\$2,100,000	0.4009	\$730,979	\$841,957
16		\$700,000	\$1,123,200	\$2,100,000	0.3747	\$683,158	\$786,876
17		\$700,000	\$1,123,200	\$2,100,000	0.3502	\$638,465	\$735,398
18		\$700,000	\$1,123,200	\$2,100,000	0.3273	\$596,697	\$687,288
19		\$700,000	\$1,123,200	\$2,100,000	0.3059	\$557,660	\$642,325
20		\$700,000	\$1,123,200	\$2,100,000	0.2859	\$521,178	\$600,304
21		\$700,000	\$1,123,200	\$2,100,000	0.2672	\$487,082	\$561,031
22		\$700,000	\$1,123,200	\$2,100,000	0.2497	\$455,217	\$524,328
23		\$700,000	\$1,123,200	\$2,100,000	0.2333	\$425,436	\$490,027
24		\$700,000	\$1,123,200	\$2,100,000	0.2181	\$397,604	\$457,969
25		\$700,000	\$1,123,200	\$2,100,000	0.2038	\$371,593	\$428,008
26		\$700,000	\$1,123,200	\$2,100,000	0.1905	\$347,283	\$400,008
27		\$700,000	\$1,123,200	\$2,100,000	0.1780	\$324,563	\$373,839
28		\$700,000	\$1,123,200	\$2,100,000	0.1664	\$303,330	\$349,382
29		\$700,000	\$1,123,200	\$2,100,000	0.1555	\$283,486	\$326,525
30		\$700,000	\$1,123,200	\$2,100,000	0.1453	\$264,940	\$305,164
<b>Total:</b>						<b>\$80,359,288</b>	<b>\$24,205,941</b>
<b>Benefit/Cost Ratio:</b>						<b>0.30</b>	

Analysis assumes all benefits and costs accrue at middle of year.

**Alternate Case Present Value of Benefits and Costs**  
**Short Loading Lines, Retrofit Option**

Real Discount Rate = 3.50%

<u>Year</u>	<u>Installation</u> <u>cost</u>	<u>Maintenance</u> <u>cost</u>	<u>Weight</u> <u>Penalty</u> <u>cost</u>	<u>[70%]</u> <u>Benefit</u>	<u>Discount</u> <u>Factor</u>	<u>Present</u> <u>Value</u> <u>costs</u>	<u>Present</u> <u>Value</u> <u>Benefit</u>
1	\$14,000,000	\$140,000	\$224,640	\$420,000	0.9828	\$14,117,582	\$412,776
2	\$14,000,000	\$280,000	\$449,280	\$840,000	0.9496	\$13,986,426	\$797,636
3	\$14,000,000	\$420,000	\$673,920	\$1,260,000	0.9175	\$13,847,996	\$1,155,994
4	\$14,000,000	\$560,000	\$898,560	\$1,680,000	0.8864	\$13,702,934	\$1,489,203
5	\$14,000,000	\$700,000	\$1,123,200	\$2,100,000	0.8565	\$13,551,847	\$1,798,554
6		\$700,000	\$1,123,200	\$2,100,000	0.8275	\$1,508,684	\$1,737,733
7		\$700,000	\$1,123,200	\$2,100,000	0.7995	\$1,457,665	\$1,678,969
8		\$700,000	\$1,123,200	\$2,100,000	0.7995	\$1,457,665	\$1,678,969
9		\$700,000	\$1,123,200	\$2,100,000	0.7725	\$1,408,372	\$1,622,193
10		\$700,000	\$1,123,200	\$2,100,000	0.7464	\$1,360,746	\$1,567,336
11		\$700,000	\$1,123,200	\$2,100,000	0.7211	\$1,314,731	\$1,514,334
12		\$700,000	\$1,123,200	\$2,100,000	0.6967	\$1,270,271	\$1,463,125
13		\$700,000	\$1,123,200	\$2,100,000	0.6732	\$1,227,315	\$1,413,647
14		\$700,000	\$1,123,200	\$2,100,000	0.6504	\$1,185,812	\$1,365,843
15		\$700,000	\$1,123,200	\$2,100,000	0.6284	\$1,145,712	\$1,319,655
16		\$700,000	\$1,123,200	\$2,100,000	0.6072	\$1,106,968	\$1,275,029
17		\$700,000	\$1,123,200	\$2,100,000	0.5866	\$1,069,534	\$1,231,912
18		\$700,000	\$1,123,200	\$2,100,000	0.5668	\$1,033,366	\$1,190,253
19		\$700,000	\$1,123,200	\$2,100,000	0.5476	\$998,422	\$1,150,003
20		\$700,000	\$1,123,200	\$2,100,000	0.5291	\$964,659	\$1,111,114
21		\$700,000	\$1,123,200	\$2,100,000	0.5112	\$932,037	\$1,073,540
22		\$700,000	\$1,123,200	\$2,100,000	0.4939	\$900,519	\$1,037,237
23		\$700,000	\$1,123,200	\$2,100,000	0.4772	\$870,067	\$1,002,161
24		\$700,000	\$1,123,200	\$2,100,000	0.4611	\$840,644	\$968,272
25		\$700,000	\$1,123,200	\$2,100,000	0.4455	\$812,217	\$935,528
26		\$700,000	\$1,123,200	\$2,100,000	0.4304	\$784,750	\$903,892
27		\$700,000	\$1,123,200	\$2,100,000	0.4159	\$758,213	\$873,325
28		\$700,000	\$1,123,200	\$2,100,000	0.4018	\$732,573	\$843,793
29		\$700,000	\$1,123,200	\$2,100,000	0.3882	\$707,800	\$815,259
30		\$700,000	\$1,123,200	\$2,100,000	0.3751	\$683,865	\$787,690

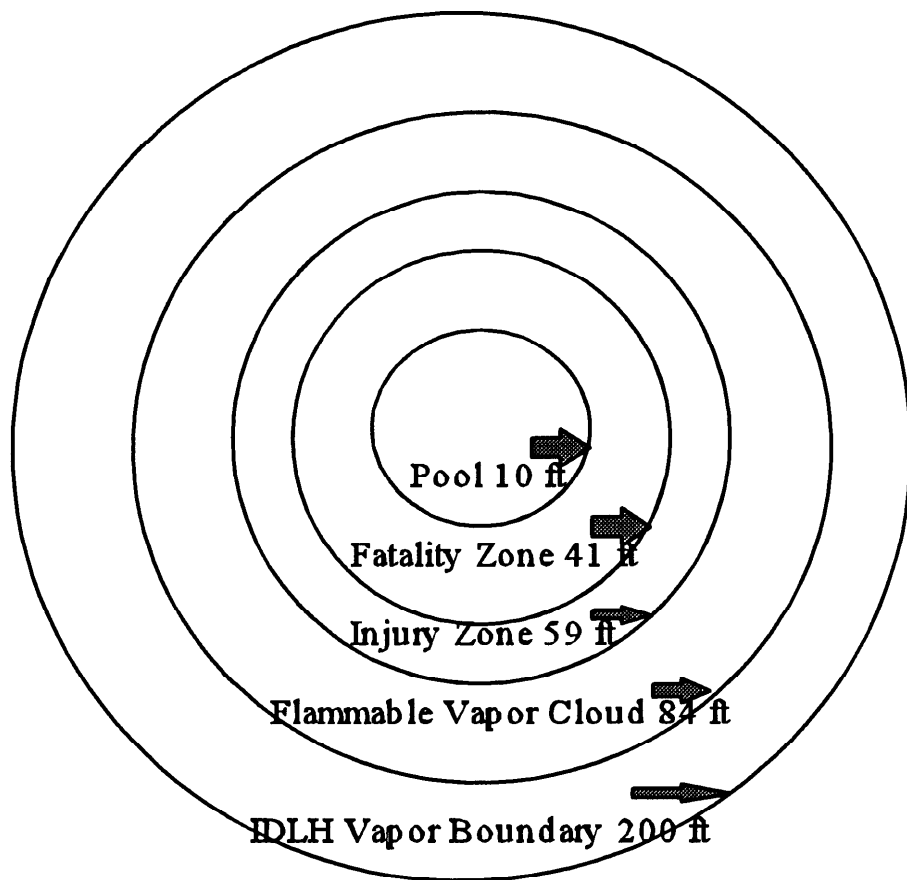
**Total: \$95,739,390 \$36,214,973**

**Benefit/Cost Ratio: 0.38**

Analysis assumes all benefits and costs accrue at middle of year.

## Appendix 5

### HAZARD ZONES FROM SPILL OF 50 GALLONS OF GASOLINE



Hazard zones are calculated using **ARCHIE** for a 50 gallon spill of gasoline. Note that effects can be enhanced by other flammable or combustible materials, such as materials or gasoline in an automobile.

The IDLH (Immediately Dangerous to Life or Health) boundary zone are computed using **ALOHA™**.

## References

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5. "An Assessment of the Risk of Transporting Gasoline by Truck," R. E. Rhoads, Pacific Northwest Laboratory, PNL-2133, November, 1978.
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8. "Hazardous Materials Risk Assessment – Year Portrait of Hazardous Materials Accidents/Incidents and Impacts," Battelle, DRAFT, November, 1998.
9. "A National Risk Assessment for Selected Hazardous Materials in Transportation," D. F. Brown and W. E. Dunn University of Illinois, DRAFT, May, 1998.